3.6

ECS Key Application Areas

DIGITAL SOCIETY

3.6. DIGITAL SOCIETY

3.6.1. SCOPE

Supporting the digital transformation throughout society
This chapter describes the type of digital innovations that are essential to stimulate an inclusive and healthy society, and which will in turn contribute to solutions for European challenges in the fields of sustainability health, well-being, mobility, security, energy, and consequently to European economic prosperity.

Europe needs digital solutions that support the individual, and at the collective level to empower society as a whole. These (smart) digital solutions will be massively driven by recent technologies such as Artificial Intelligence (AI), robotics, 6G, virtual reality (VR) and augmented reality (AR),possibly brain–computer interfaces (BCIs). In particular, the recent spectacular advent of Generative AI boosted the application of AI technology and its use for society. These technologies are now shaping new ways of how people use and interact using technological solutions, with each other, and with society and the environment. Digital innovations should facilitate individual self-fulfilment, empowerment and resilience, collective "inclusion" and safety, as well as a supportive infrastructure and environment. However, these innovative technologies, especially AI, also bring risks. AI can bring many advantages, but also lack of transparency, bias and discrimination, privacy concerns, ethical dilemmas, security risks, unwanted dependence, job displacement, and misinformation and manipulation, to name the most important[1].

Furthermore, such transformations are also introducing a wide range of ethical considerations, as digital innovations need to address societal concerns in a sustainable way, guaranteeing participation and reducing inequality. A human-centred approach is therefore a key aspect of the EU's approach to technology development. It is part of European social and ethical values, (social) inclusiveness, and the creation of sustainable, high-quality jobs through social innovation.

In summary, we see four areas to be addressed as our Major Challenges: facilitating individual self-fulfilment, facilitating empowerment and resilience, facilitating inclusion and collective safety, and facilitating supportive infrastructures and sustainable environments.

3.6.2. APPLICATION TRENDS AND SOCIETAL BENEFITS

3.6.2.1. External requirements

To guarantee economic and societal growth in Europe, digital inclusion and transformation requires tools and infrastructures in application domain roadmaps as described in the other

[1] The 15 Biggest Risks of Artificial Intelligence (forbes.com)

chapters. Digital technology is permeating every aspect of society and is an important instrument of change.

People's expectations of the future impact of technology are broadly positive, but also involve specific concerns around employment, income, safety, equality, and trust. The impact of science and technological innovation on prosperity, individual well-being, sustainability, fairness, and trust is continuously growing, which underlines the importance of investing in our digital strategy today.

This can be further illustrated by the spectacular advent of AI-technology (see figure 3.6.1): the AI market has seen significant growth, offering numerous opportunities for new players. AI, which encompasses technologies capable of tasks requiring human intelligence, is revolutionizing sectors such as healthcare, finance, transportation, and customer service. The market's expansion is largely driven by the increasing demand for automation and efficiency, as businesses adopt AI to streamline operations, reduce costs, and enhance productivity. Additionally, advancements in machine learning and the abundance of big data have further fuelled AI's growth, enabling systems to improve over time and extract valuable insights for better decision-making.

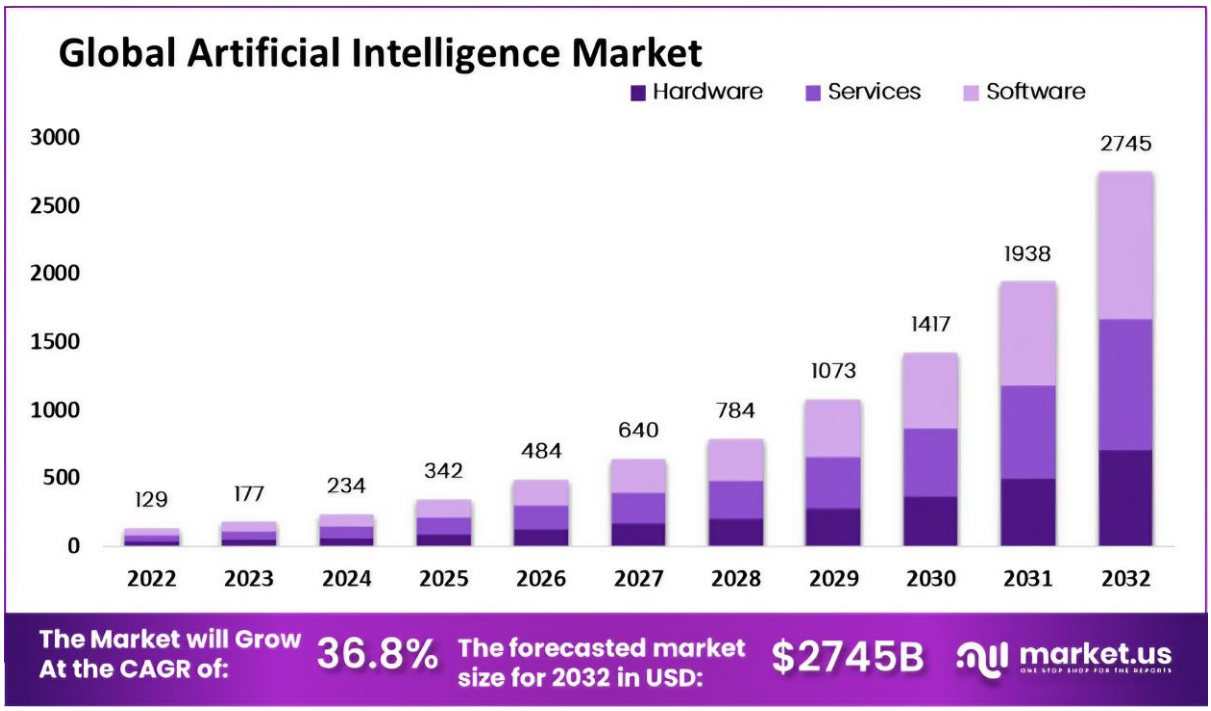


Figure 3.6.1 Growth of global AI market
(source https://market.us/report/artificial-intelligence-market/)

In striving to guarantee European sovereignty to support European digital societal goals, safety, equality, and trust are key requirements. But what does this mean for electronic components and systems (ECS) for our society? Ubiquitous connectivity ("*everywhere and always on*"), online services and social media ("*always online*") drive people to rely on intelligent applications and the services they offer. Public and private infrastructures will increasingly be connected, observed, and controlled via digital infrastructures ("*continuous monitoring*").

Two important further drivers for European society and economy – from a human-centred approach on AI perspective – are lifelong learning and training, as well as being able to work anywhere, any-place. The trend to work from home whenever possible (earlier triggered by the Covid pandemic) has continued, and people are combining work and private life in a better way. In rural areas, as well as in cities, it should be easy to work either from home or remotely in distributed groups/workforces. This can be facilitated through living labs and learning factories at both a personal and collective level.

3.6.2.2. Societal benefits

All of European society will benefit from a major (AI-based) evolution in intelligent systems, on both the individual and collective levels:

- The benefit of digital inclusion for all individuals will involve employability through lifelong learning and training, and the personal well-being of individuals. To achieve these, the key ambition is to maximise the individual development of citizens.
    - How? By ensuring personal resilience, enabling lifelong learning and development, and stimulating employability. Human-centred solutions will optimise services to the needs and capacity of each individual, for applications in areas such as healthcare, lifestyle, coaching, training, and working from home or remotely collaborating in a "distributed" workforce. This will boost employee productivity, improve their work/life balance, and foster better mental health, and reduce pollution from commuters.
- The overall individual benefit is "well-being". A factor such as "prosperity" means job security, material living standards and the right to have the optimum education, any time, any place. On an individual level, well-being means health for every one of every age, and also adequate housing, ensured safety, protected privacy, reliable and ubiquitous digital infrastructures, in addition to social connectedness and more intense social cohesion. Our key objective is to empower and protect the individual.
    - How? By ensuring acceptable and trustable AI technologies to increase inclusion and prevent exclusion, protecting citizens against identity theft, and providing a protective environment against new virus infections; in addition, through lifestyle monitoring and coaching, to enable and support healthier lifestyles.

- The benefits of digital inclusion. A society resilient against setbacks, and the societal acceptance of novel technologies will achieve the key ambition of safeguarding a collective society and well-being for all.
    - How? By societal and digital inclusion, providing societal access for all, and ensuring collective resilience against setbacks. Also, the elderly will be supported to continue their social participation, which will reduce feelings of loneliness, improve their well-being and health, but provide reassurance that their precious experience can still be used.

- On an environmental level, the benefits are a physical and digital sustainable environment, intelligent Infrastructure management, stability and resilience against

threats, and agreement on fall-back solutions in times of crises. The main aim is to contribute to a supportive infrastructure and environment.

- How? By providing reliable and resilient infrastructures, protecting society against destabilising forces, establishing a sustainable environment, and securing controlled climate change. Monitoring and intelligent control of infrastructures will also contribute to a sustainable environment by solutions that address, for example, optimal use of natural resources, reduction of pollution and crisis management.

"Sustainability" in a wide sense implies both environmental and economic sustainability, as well as equal opportunities for all people. It is related to fairness and trust in our societies. It must be ensured that AI-based systems will take European-style human values into account by design (to which the AI-act is contributing). Continuation of a human-centred approach is therefore a key requirement. As such, "FAIRness" (findability, accessibility, interoperability, and re-use) will help to shape future applications too.

3.6.3. MAJOR CHALLENGES

Enabling and ensuring a digital society implies various aspects to be facilitated by trustable ECS products and services. To structure these aspects, we distinguish between the individual or collective context and the internal or external scope. This leads to the matrix shown in 3.6.2 below.

Each of these four areas relates to one of the following Major Challenges:

- **Major Challenge 1**: Facilitate individual self-fulfilment.
- **Major Challenge 2**: Facilitate empowerment and resilience.
- **Major Challenge 3**: Facilitate inclusion and collective safety.
- **Major Challenge 4**: Facilitate supportive infrastructures and sustainable environments.

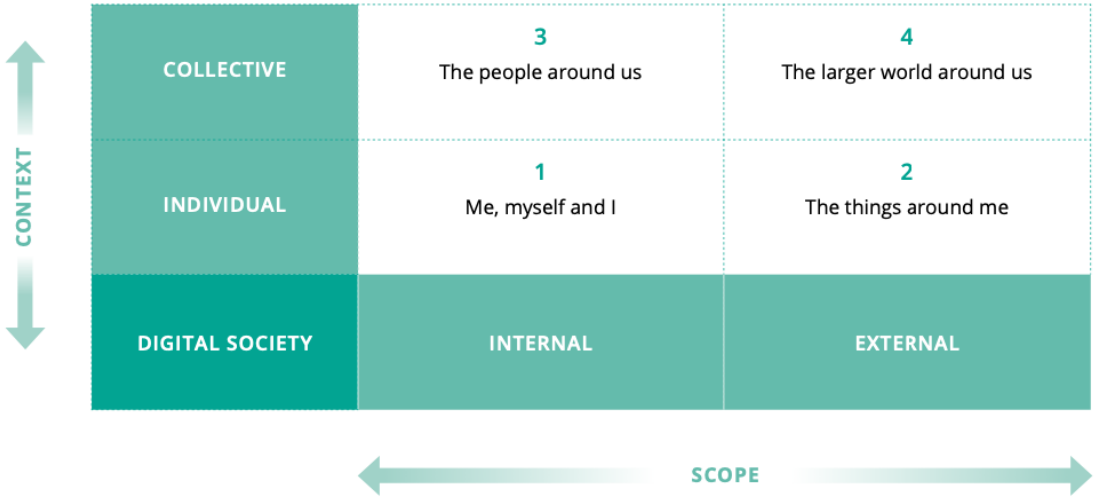


Figure 3.6.2 - Structuring the Major Challenges in scope and context

3.6.3.1. Major Challenge 1: Facilitate individual self-fulfillment

3.6.3.1.1. Status, vision and expected outcome

Ambition: to maximise the individual development of citizens.

- Provide empowerment to citizens and ensure personal resilience.
- Enable lifelong learning and development for both children and adults (serious gaming, including AI-based AR/VR).
- Give citizen more freedom to do their work wherever they want/need.
- Stimulate employability (e.g. by gamification[2], tool and means for stimulation efficient remote work).
- Improved human–machine interaction solutions for perception, reasoning, and autonomy, with interaction being adaptive to the user's abilities.

To maximise the empowerment and self-fulfilment of citizens, Europe has to strive for lifelong learning, employability, and the freedom to work wherever one resides, as well as optimal well-being in the context of an independent and pluralistic media. These enable lifelong empowerment by keeping citizens informed and facilitate the flow of educational content. Educating through the media is an important means to develop valuable skills that will help to end violence and eradicate forms of discrimination (such as sexism and racism). More fundamentally, the media encourages the acquisition of civic knowledge and facilitates discussion concerning current issues, while at the same time entering new frontiers of engagement using on-demand and interactive paradigms, and in employing AR/ VR technologies backed by trustable 5G/6G connectivity.

The 30-year career has become a thing of the past. Education does not end after school; individuals need to keep on learning throughout their careers to stay up to date and adapt their skills as the world changes at an unprecedented rate. To better support lifelong learning, technologies are needed that encourage collaboration, foster autonomy, and responsibility, and implement learning initiatives. Technological advancements such as cloud computing, mobile devices and innovative web technologies are still relatively new additions to the workplace that must be further explored[3].

To provide the citizen with more freedom to do their work wherever they want or need, Europe must ensure the availability of trustable high-bandwidth secure connections (wired and wireless) at all possible locations one could use to work from. This should be reinforced by easy and secure access to cloud applications, and novel AI-based solutions to automate processes, analyse data, guide the user in decision-making, and to minimise repetitive work.

Advanced technologies, including smart automation and AI, have the potential to not only raise productivity and GDP growth, but also to improve well-being more broadly, as well as offer a healthier life and longevity, and greater leisure time. Studies have shown that, besides income, the following factors contribute to individuals' well-being and self-reported life satisfaction: social life, use of leisure, health, spouse/partner, job, flat/house, and the amount

[2] Gamification: The application of game design elements and principles in a non- game context.

[3] https://www.trainingjournal.com/articles/ opinion/how-promote-lifelong-learning- using-technology

of leisure[4]. Innovative technologies in the digital society can, and will, influence all these factors.

There are ample examples of relevant tools which utilises gamification to offer the lifelong free and open learning of languages and brings massive open online course (MOOC) platforms to the public. Additionally, AI-tools that are based on Large Language Models (such as ChatGPT, Claude and others) are beneficial for the individual development of citizens in several ways (access to knowledge, skill development, critical thinking, etc.). However, no tool can replace the richness of human interactions, creativity and experiences in personal development and interaction.

3.6.3.1.2. Key focus areas

High-priority research and development and innovation (R&D&I) areas:

- Digital inclusion: tools, infrastructure, training, connectivity.
- Online education and examination: VR/AR training and support.
- Improved human–machine interaction (HCI) solutions.
- Support devices: wearables, robots, cobots, etc.
- Nudging and serious gaming: for personal development and healthier lifestyles.
- The trusted element: how to be sure that not more is done (under the surface)

To improve the awareness of our body's condition to external or internal stimuli, smart systems can provide support for disabilities, or a personal coach and trainer to identify behaviour to be avoided (wrong body position and other unhealthy habits), as well as possible future injuries or disorders. Smart systems can also offer an immersive experience through vision, gaming, and sensory interaction by way of VR or AR. Consumers can be offered the immediacy, individualisation, interactivity, and immersion they expect from media content consumption ("even better than being there").

A healthier and more comfortable environment can be offered based on personal preferences (control of temperature, humidity, air flux, etc.), in the context of running activities and clothing, and by adapting lighting and acoustic quality to one's own sense of well-being. It also provides the capability to comfortably communicate and interact remotely with people, institutions, and sellers, possibly without leaving home, saving time for self- development and leisure.

Selective automation, AR at work and a range of feedback tools can help boost satisfaction and give more meaning to work. This is a particularly important element for the millennial generation, which -according to surveys- tends to place more emphasis on work satisfaction than on income (above a certain income level). Technological advances have made it possible to place audiences in the middle of the action and to offer them immediacy, individualisation, interaction, and immersion without the need for them to actually be there in person. This will further change consumption patterns and create new business opportunities.

[4] https://www.mckinsey.com/featured- insights/future-of-work/tech-for-good- using-technology-to-smooth-disruption- and-improve-well-being

Furthermore, we have to mitigate the risks of AI and other functionality that is based on massive data storage in the cloud. This can be done in different ways, such as:

- Introduce fake news detection by analysing AI-generated content on social media
- Develop technologies to prove the source of content creation, for instance by showing that a video was created with an actual camera. If part of the processing is done externally and/or in the cloud, add traceability of what was done where.
- Add watermarking to created content to proof that it is not artificial.
- Secure control of systems used for content creation, for instance by prevention of production equipment to be taken over by external aggressors in big events like Olympic Games, Eurovision song festival, European and World championships, etc.

Required R&D&I developments within ECS

Taking the above into account, specific R&D developments are necessary within ECS technology, as shown in

Specific R&D developments necessary	**ECS technologies**							
Major challenge 1: "Facilitate individual self-fulfilment"	Process techn, equipm, materials & manufact.	Compoinents, miodules and system integration	Embedded SW & Beyond	System of Systems	Edge Comp. & emb. AI	Connectivity	Architecture & Design	QRSC
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4
Reliable, dependable and secure SW and HW	x	x	X	x	x	x	x	X
Mature human systems interaction methods				X			X	X
Trustable AI/Machine Learning algorithms		x			X			X
Energy-efficient HW and SW solutions (e.g. for IoT devices, wearables)	X	x	X		X			
Seamlessly operating SW (e.g. for IoT devices, wearables)		X	X	X		X		
Ubiquitous, reliable, and energy-efficient connectivity	X	X	X			X	X	X

Figure 3.6..

Specific R&D developments necessary	**ECS technologies**							
Major challenge 1: "Facilitate individual self-fulfilment"	Process techn, equipm, materials & manufact.	Compoinents, miodules and system integration	Embedded SW & Beyond	System of Systems	Edge Comp. & emb. AI	Connectivity	Architecture & Design	QRSC
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4
Reliable, dependable and secure SW and HW	x	x	X	x	x	x	x	X
Mature human systems interaction methods				X			X	X
Trustable AI/Machine Learning algorithms		x			X			X

Energy-efficient HW and SW solutions (e.g. for IoT devices, wearables)	X	x	X		X			
Seamlessly operating SW (e.g. for IoT devices, wearables)		X	X	X		X		
Ubiquitous, reliable, and energy-efficient connectivity	X	X	X			X	X	X

Figure 3.6.3 - Required R&D&I developments within ECS –Major Challenge 1

3.6.3.2. Major Challenge 2: Facilitate empowerment and resilience

3.6.3.2.1. Status, vision and expected outcome

Ambition: empower and protect the individual citizen.

- Increase inclusion and prevent exclusion.
- Protect citizens against cyber-fraud (scams) and identity thefts; provide privacy.
- Enable safe smart homes with ubiquitous connectivity.
- Ensure acceptable AI technologies.

Diversity and inclusion within societies are increasingly recognised as crucial for equality at work and economic development. Research has established a strong link between gender equality in society, attitudes, and beliefs about the role of women, and gender equality in work[5]. Technology can improve equality at work – for instance, by revealing pay gaps and biases, and helping de-bias recruitment. It can also improve equal access to essential services – for example, biometrics and cloud technology can contribute to increasing the diffusion of microfinance to women and underserved populations. Technology can also help enforce inclusive legal rights, policies, and social norms. While e-voting still poses a number of cybersecurity challenges, it can support diversity by facilitating the vote for vulnerable and marginalised parts of society. Finally, technology can help with physical security and autonomy for minority groups through objects and digital communications tools that reduce or mitigate exposure to risk – for example, connected devices such as smart bracelets can enable women to signal an assault and call for help.

Reliance on technology comes with many benefits, but also brings new risks[6]. The radical nature of the ongoing technology transition could result in risks that are not just an extension of the previous challenges but require fundamental changes to core aspects of our society, including how we think about our identity, security, and rights. Concerns about technology are justified by recent events, such as security breaches in prominent companies, data theft and information misuse. In addition, AI provides more powerful examples of potential risks. Its full potential can be used only if we fully rely on it for decision-making, allowing it to process data beyond the human ability to cross-check and verify. This depends on a high level of trust, raising questions about, and requiring, new technical solutions that take into account explainability, accountability, trustworthiness and ethics.

[5] McKinsey Global Institute: "Tech for Good: Smoothing disruption, improving well- being", May 2019, p 42 and p 43.

[6] McKinsey Global Institute: "Tech for Good: Smoothing disruption, improving well- being", May 2019, p 58.

In the early '20's we have experienced the necessity of a connected smart home and an adequate home office during the pandemic. However, the availability of high bandwidth connectivity is not evenly distributed geographically across Europe.

Machine learning is essential for a resilient future. AI will have a far greater chance of successful implementation if there is a focus on four key areas: augmented intelligence; intelligent automation; assessed intelligence; and adaptive intelligence. Augmented intelligence concerns augmenting and thus improving the productivity of humans. Intelligent automation is about building systems that integrate humans and machines in productive ways (instead of just replacing humans entirely with machines). Assessed intelligence is all about making models robust by evaluating them rigorously and continuously. Finally, adaptive intelligence involves developing more resilient systems that can adapt to changing circumstances by shifting to a causal inference paradigm.

3.6.3.2.2. Key focus areas

High-priority R&D&I areas:

- Reliable and ubiquitous digital infrastructures.
- Access control/intrusion detection/surveillance.
- Provide protective environment and tools against virus infections.
- Protect individual citizens against cyber-fraud (scams) and identity theft.
- Off-grid living and emergency survival.

Since the Covid pandemic, working from home has become an integral part of how knowledge workers do their work. To further enable working from home (or wherever and whenever one wants), wireless and wired infrastructures will have to be further improved (through increased reliable bandwidth, lower cost, better geographical coverage and finer granularity), security of connections will have to improve to protect the worker at home (as will the company using a distributed workforce with many internet connections) against cyber-attacks, and the theft of personal and/or company information. New functionality running in the private/public cloud will be needed to support real-time actions that may suffer from latency issues over the internet, as well as to support the worker in decision-making. Examples here are control of robotic surgical devices, remote control of robots in industrial processes, remote control of cameras in security applications and live television productions. Other professions, such as translation services, voice recognition and all kind of analytical algorithms for data analysis, also come to mind.

To create equal opportunities, innovative research should include: speech-generating devices (SGD) to help people with speech disorders; exoskeletons that empower disabled people in their everyday life; semi-autonomous vehicles that increase mobility for people with deafness and blindness; smart objects linked to geospatial information to improve women's security (e.g. invisible SOS buttons); augmentative and alternative communication tablets that help paralysed patients; VR solutions that provide realistic experiences for people with physical disabilities; and smart glasses that can be used to help people with autism on cognitive, social and emotional skills.

Given the experience of the past pandemic, we learned that Europe needs better technologies: (i) to fight and contain the rapid spread of highly contiguous diseases (such as Covid-19); and (ii) to ensure that public health institutions can maintain their capacity to meet the ever-increasing needs caused by such a pandemic[7]. The in-depth analysis provided by the European Parliamentary Research Service's "Ten Technologies to Fight Coronavirus" identifies the importance of AI, blockchain, open-source-, telehealth- and gene-editing technologies, 3D printing, nanotechnology, synthetic biology, and drones and robots for fighting pandemics.

Intrinsically, technology is neither good nor bad – it is the use to which it is put that makes the difference. Malicious uses of technology include mass disinformation campaigns and cyber-attacks that seek to jeopardise national security, and cyber-fraud that targets consumers. This duality has always existed. Over the coming years, technologies such as the IoT, smart robotics, automation and AI are likely to follow the same pattern. It is up to European technology specialists to ensure that the technologies developed not only support diversity and inclusion, but also protect both the individual and groups against cyber-attacks, theft of personal information and unwanted intrusion into the personal environment.

Required R&D&I developments within ECS

To facilitate empowerment and resilience, specific R&D developments are necessary within ECS technology, as shown in

Specific R&D developments necessary	**ECS technologies**							
Major challenge 2: "Facilitate empowerment and resilience"	Process techn, equipm, materials & manufact.	Compoinents, miodules and system integration	Embedded SW & Beyond	System of Systems	Edge Comp. & emb. AI	Connectivity	Architecture & Design	QRSC
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4
Reliable, dependable and secure SW and HW	X		X			X	X	X
Trustable AI/Machine Learning algorithms					X			X
Advanced cyber-security and privacy methods and tools		x	x			X	X	X
Ensuring of safety and resilience based on ECS technologies		X	X	X	X	X	X	X
Energy-efficient and dependable HW and SW solutions (e.g. for IoT devices, wearables)	X		X	X	X		X	X
Seamlessly operating SW (e.g. for IoT devices, wearables)		X	X	X		X		
Ubiquitous, reliable, and energy-efficient connectivity and localization	X	X	X			X	X	X
Secure broadband connectivity based on 5G systems and beyond	X	X	X			X		X
Distributed (production) systems		X	x	X	X	X	X	X

[7] https://www.europarl.europa.eu/ RegData/etudes/IDAN/2020/641543/ EPRS_IDA(2020)641543_EN.pdf

Figure 3.6..

Specific R&D developments necessary	ECS technologies							
Major challenge 2: "Facilitate empowerment and resilience"	Process techn, equipm, materials & manufact.	Compoinents, miodules and system integration	Embedded SW & Beyond	System of Systems	Edge Comp. & emb. AI	Connectivity	Architecture & Design	QRSC
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4
Reliable, dependable and secure SW and HW	X		X			X	X	X
Trustable AI/Machine Learning algorithms					X			X
Advanced cyber-security and privacy methods and tools		x	x			X	X	X
Ensuring of safety and resilience based on ECS technologies		X	X	X	X	X	X	X
Energy-efficient and dependable HW and SW solutions (e.g. for IoT devices, wearables)	X		X	X	X		X	X
Seamlessly operating SW (e.g. for IoT devices, wearables)		X	X	X		X		
Ubiquitous, reliable, and energy-efficient connectivity and localization	X	X	X			X	X	X
Secure broadband connectivity based on 5G systems and beyond	X	X	X			X		X
Distributed (production) systems		X	x	X	X	X	X	X

Figure 3.6.4 - Required R&D&I developments within ECS – Major Challenge 2

3.6.3.3. Major Challenge 3: Facilitate inclusion and collective safety

3.6.3.3.1. Status, vision and expected outcome

Ambition: safeguard collective society and well-being for all.

- Societal and digital inclusion.
- Provide societal access for all.
- Ensure collective resilience against setbacks.

Although European countries have diverse types of welfare models, they also share a history of robust social protection and a focus on inclusive growth, which has been under stress in recent years[8]. There could be cracks in the sustainability of the EU social contract over the next decade caused by six trends: ageing; digital technology, automation, and AI; increased global competition; migration; climate change and pollution; and shifting geopolitics. Based on these trends, inequality may rise again, and divergence within Europe could increase.

Inequality at work may emerge through a combination of: (i) automation and the substitution of labour; and (ii) corporate diffusion dynamics, leading to a competitive disadvantage among

[8] Testing the resilience of Europe's inclusive growth model, McKinsey Global Institute, December 2018, p4.

non-adopting firms. To prevent reduced employment and secure real wage growth, automation using AI, robotics and other innovative technologies should lead to significant productivity gains. In general, occupations based on more repetitive and non-digital tasks will be taken by workers with low education and skills, who will therefore be the first to experience pressure on wages.

Collective growth and well-being are not only determined by equality at work, but also by individual development supported by collective interactions. Studies have shown that active social relationships increase health and longevity by improving key biomarkers of physical health. A lack of interaction causes a subtle decline in mental health by reducing attention, learning, memory, and decision-making skills. In short, our bodies reward us for social interaction and punish us for isolation by negatively impacting mental and physical health. Direct interactions with family and friends, participating in team sports and, for instance, visiting an event with friends are particularly important. No technology can fully replace direct contact. However, during the former Covid pandemic, we had to rethink our social interactions, and to adapt technologies to increase and improve social interactions – not just between individuals, but also between individuals and groups, as well as between different groups. How can improved technologies support existing social interactions, and secure healthy digital social interactions in cases of setbacks?

It may seem obvious that the Electronic Components and Systems used are trustable devices and technology, but this is an important boundary condition in Europe.
In addition, collective safety can be enhanced by solutions that directly address specific communities or groups of people the individual is a member of, such as family, friends, neighbourhood, region, (sports)club or association. These solutions can either have a warning or alerting function (e.g. contamination, local fire, local air pollution, incident of violence), but can also be of a supporting nature – for instance, alerts or instructions in combination with collective supporting devices (e.g. automated external defibrillator (AED), diagnostics, measurement).

3.6.3.3.2. Key focus areas

High-priority R&D&I areas:

- Digital inclusion: tools, infrastructure, training, connectivity.
- Collective safety: secure access control, surveillance, pandemic control, prevention of misinformation without limiting freedom of expression.
- Safe environment for living, working and transport: buildings and bridges resilient against earthquakes through continuous monitoring (e.g. fibre-based stress sensors).
- Emergency/crisis response solutions and services.
- Dynamics of society: systemic change.

As Europe wants to play a key role in digital inclusiveness, it is important to ensure availability and accessibility of solutions to enable remote education, learning, training and assessment of professionals, students, and consumers in all regions (both cities and rural areas). Also, solutions to support social inclusiveness for people of all age should become available.

The EU has stated, in their document on orientations towards the first strategic plan for implementing Horizon Europe[9], that the interaction of science, technology, social sciences and humanities will be crucial in this respect, as will be the input of the creative sector and artists to sustainable inclusive innovation and human- oriented technologies.

To facilitate inclusion, more research will be needed on education, simple human–machine interfaces and digital technology interfaces that avoid the digital split between high- and low-educated citizens. In addition, remote presence, and remote connectivity to keep people connected even if they are not in the same location, trustworthy social media, serious gaming, media consumption and AR/VR will be key.

To safeguard digital inclusion, education is one of the most important research areas. Examples here are the use of AI to build personalised journeys and enhance learning outcomes, to adapt curriculum to individual student needs, digital support and nudging systems to reduce the administrative burden on teachers, tablet-based learning to improve results and decrease distress for students with dyslexia, automation of administrative tasks to free up time and resources for educational professionals, wearable devices that provide real-time support to pupils, eye-tracking solutions to adapt students' learning experiences, and use of AR/VR to provide immersive experiences to civilians in less well-served areas.

AR may improve connectedness for remote places, reducing the need for commuting or business travel. It could also enable consumers to enjoy an event together even if they are not physically at the event.

There are still several challenges to effectively take full advantage of AI in video creation and consumption. One is the size of video data. Results are only accurate when algorithms are fed with millions of observations. Technologies therefore have to be deployed, and strategies have to be implemented to gather data at scale to harness the full power of AI techniques. However, size creates another challenge: datasets need to be manually labelled by humans to train the model, making the process expensive and cumbersome. Many new techniques are becoming available to overcome the challenge of data categorisation, such as reinforcement learning, generative adversarial networks, transfer learning and "one- shot learning" and large-language-models. In consumer-facing applications, such as marketing and recommendation algorithms, AI models may need to be refreshed continuously due to changes in the environment that drives them. Continuous updates to AI models are expensive. Other challenges relate to data management and data gathering: to create accurate results with AI, and thus value, diverse types of data have to be managed in a unified manner. This includes audience data, operational data, and content data (metadata). Also, "selection bias" (i.e. the data gathered is not representative of the population studied) has to be prevented to exclude wrong conclusions in a perfectly working model.

To facilitate collective safety, further research is required on secure access control, intrusion detection, (video) surveillance of security sensitive areas, and individual and collective activity tracking.

[9] https://ec.europa.eu/research/pdf/horizon- europe/ec_rtd_orientations-towards-the- strategic-planning.pdf

Secure access control as a service (ACaaS) is growing in relevance. This combines biometric readers and identity access management and can be integrated with other physical security systems (e.g. video surveillance) and building automation systems. Combined with building occupancy management systems, it can deliver valuable information on the location of staff and visitors, and in the event of an emergency to rapidly clear the building.

Both the former Covid pandemic and the military conflicts on our continent has brought new physical security requirements. In addition to regular cameras, thermal cameras as well as different sensing devices could be added at the entrance of buildings and venues to measure people's state (e.g. temperature) and investigate if they do not carry dangerous materials as they enter premises. Physical access control, enriched with video security evidence, can provide important insights on where an infected individual has been, which doors they have used and who else may have come into contact with those doors and that individual. It can also provide these insights for more general security purposes.

More research on AI security solutions will ease the work of security operators. AI software can analyse images and audio from video surveillance live streams and recordings, and use image recognition algorithms to recognise faces, objects, and events, more than a hundred times faster than human operators. AI algorithms can also be used to carry out event detection, scene reconstruction, video tracking, object recognition, and (re)-identification, 3D pose estimation, motion estimation and image restoration. Video surveillance may be extended with freely moving cameras mounted under drones to recognise unusual behaviour in crowds from a high altitude, to monitor hazards such as fires, floods, or erupting volcanoes, and to recognise criminal faces and follow targets. Since drones are airborne, they need fast mobile and wireless communications. Low-latency broadband technologies such as 5G/6G can improve the precision and speed of their response times and enable high-speed communication to a nearby edge computing device.

Video quality should be further improved to support deep-learning algorithms, and to improve the video experience in media consumption: the spectral range and colour gamut can be extended, sensitivity must increase for low light use and especially dynamic range for better performance under all (and changing) lighting conditions as this has the greatest impact on the perception.

AI video and audio algorithms will have to be transparent and explainable. Dedicated video and audio technologies will be required to prevent and trace fake video and audio used to create misinformation in (social) media. Audio and video equipment used to create content must be able to watermark content streams to prove authenticity, and metadata should be added to the streams to prove what processing activities have taken place from image capture until display at home. Next to that equipment used for content creation based on open public infrastructures (such as internet and 5G) and with processing or control activities in the cloud must be better secured to prevent unwanted take-over by aggressors.

Required R&D&I developments within ECS

To facilitate inclusion and collective safety, specific R&D developments within ECS technology are necessary, as shown in Figure 3.6..

Specific R&D developments necessary	ECS technologies							
Major challenge 3: "Facilitate inclusion and collective safety"	Process techn, equipm, materials & manufact.	Compoinents, miodules and system integration	Embedded SW & Beyond	System of Systems	Edge Comp. & emb. AI	Connectivity	Architecture & Design	QRSC
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4
ECS technologies for AR/VR and high-quality video/videoconferencing	X	X	X		X	X	X	
Tools, methods, SW and HW technologies for extensive and ubiquitous use of AI/Machine Learning	X		X		X	X	X	
Advanced cyber-security and privacy methods and tools						X	X	X
Intelligent connected IoT devices using new sensors for safety and resilience of EU societies	X	X	X	X	X	X	X	X
Ubiquitous, reliable, and energy-efficient connectivity and localization	X	X	X			X	X	X
Secure broadband connectivity based on 5G systems and beyond	X	X	X			X		X

Figure 3.6.5 - Required R&D&I developments within ECS – Major Challenge 3

3.6.3.4. Major Challenge 4: Facilitate supportive infrastructure and a sustainable environment

3.6.3.4.1. Status, vision and expected outcome

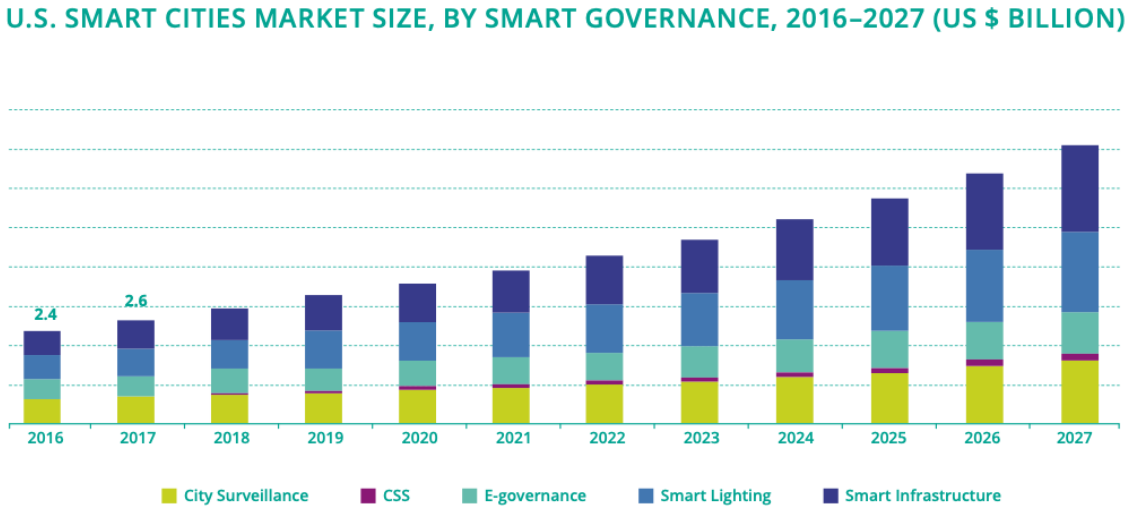
Ambition: contribute to a collective supportive infrastructure and environment.

- Provide trustworthy, reliable, and resilient infrastructure.
- Establish a sustainable and secure environment.
- Provide means for controlled climate change.

To fully benefit from the power of digitisation, Europe must enable a supportive infrastructure and environment. Given the rapid pace of change, this requires companies to get their technology, people, and culture ready to join the digital transformation. This should be achieved by providing a reliable and resilient digital infrastructure (with ubiquitous and continuous connectivity), protecting society against destabilising forces and establishing a secure and sustainable environment. The former includes preventing harmful use of the internet (e.g. manipulation of elections, misinformation such as "deepfakes" and "cheapfakes", but also identity theft and phishing), which are covered by Major Challenge 3. The latter includes securing controlled climate change (as stipulated in the Green Deal) by providing adequate means that can be utilized by citizens. Furthermore, monitoring, and intelligent control of infrastructures, essential resources, and their recycle process (especially in the urban environment) will contribute to a sustainable environment.

The vision is to introduce new digital products and services that contribute to a sustainable lifestyle in all areas of human life, including cradle-to-cradle and circular economy aspects. We are addressing the following aspects:

- Comprehensive assessment of resource usage to identify largest areas of energy and materials consumption and CO_2 production. As well as air quality monitoring systems, they need to offer solutions for lighting, heating, computing with reduced usage of energy, and other resources. In addition, solar panels and batteries, home-grown vegetables and city farming systems are key.
- Providing smart systems based on IoT and unmanned/robotic platforms that provide secure environments and support digital business life with the minimum amount of resources (energy, water, paper, travelling, etc.), ensuring a highly efficient, productive, and sustainable working environment.
- Smart water management to protect resources. Intelligent management of energy in public spaces such as football stadiums and railway stations, including smart street lighting. Promoting green areas in cities and enabling citizens to provide their own sustainable solutions. Reduction of (food) waste in supermarkets and restaurants, as well as resource recycling.
- Development of new digital solutions that can be used by citizens themselves or be used to stimulate societal attitudes and activities towards sustainability and addressing climate change, e.g. car sharing, use of public transportation, bikes, and e-scooters.



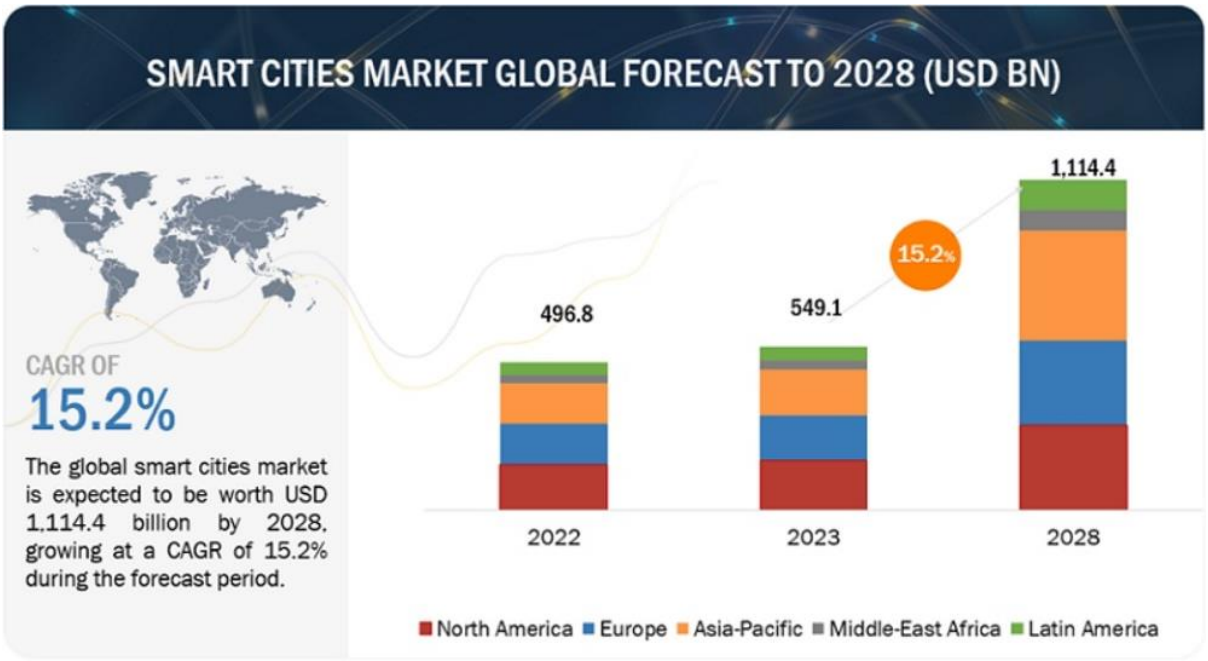


Figure 3.6.6 - Growth of smart cities market (Source: www.marketsandmarkets.com)[10]

The European approach to working with regard to digitalisation will be focused on the preservation of our democratic system, and on values such as trust and cooperation. Ethical requirements will include fairness, accuracy, confidentiality, transparency, accountability, explainability, trustworthiness and absence of bias. This involves offering AI capability maturity programs to companies that use AI in their designs, to coach them in the best ethical points of view. In this way, products will become more resilient, accessible, reliable, and trustworthy, and hence ready to take part in the new European digital society (with an effective AI act).

3.6.3.4.2. Key focus areas

High-priority R&D&I areas:

- Physical infrastructure management/physical resilience and security.
- Intelligent infrastructure management (intelligent buildings, city-owned infrastructure, synergies with industry, etc.).
- Digital solutions and infrastructure for resources management, digital resilience, sustainability, e-government and citizen support.
- Resource and environment monitoring (air, water, etc.) and feedback to enable more effective management.

To further improve digital transformation towards more secure, effective, and sustainable environments, new digital tools employing IoT, unmanned vehicles/robots and AI/ML-enhanced algorithms have to be infrastructures, investments should be aimed at enhancing

[10] Source: Grand view Research: "Smart Cities Market Size, Share & Trends Analysis" Report by Application (Governance, Environmental Solutions, Utilities, Transportation, Healthcare), By Region, And Segment Forecasts, 2020 – 2027. See https://www.grandviewresearch.com/ industry-analysis/smart-cities-market

infrastructure coverage and quality . Also, outcomes have to be influenced through legal frameworks and by setting standards.

Intelligent buildings will require security, eco-friendship and building management. Security systems such as access control and cybersecurity were covered under Major Challenge 3, but the further development of smart lighting, air quality monitoring and control, and IoT-based real-time monitoring of electric, water and gas meters to increase the energy efficiency of buildings with the help of distributed energy systems will improve the well-being of occupants and reduce the carbon footprint of buildings. Smart technology (e.g. sensors placed around radiators, boilers, pumps, and other machinery to detect critical levels of noise, vibration, or heat) will enable facility managers to save maintenance costs by switching from a reactive to a predictive maintenance model.

Cities are very complex organisms. They combine a variety of means allowing for mobility, city infrastructure providing diverse types of media (gas, water, energy, etc.), and citizen-oriented services that increase their quality of life. It is predicted that by 2050 between 68% and 90% of the global population might live in cities, from small municipalities right up to megacities11. This means that, in the near future, technical means will be required to enable digital solutions for more sustainable development in cities of all size and wealth. Available technologies from tech giants such as IBM, Microsoft, Amazon, Google, and Cisco raise concerns from city managers about data privacy policies, and the very high maintenance costs caused by licence fees and the potential for vendor lock-ins[12]. Available open-source solutions – such as the Red Hat integration platform, which could be used in smart city applications – can also easily be acquired by large companies such as IBM[13] to be integrated with their company product portfolio offered commercially. This means that, in such a dynamically changing world, open-source solutions that are widely available, promoted and deployed within EU (such as FiWARE[14]) have to be developed to protect European sovereignty and values. Additionally, due to the rich industrial heritage in many EU countries, opportunities for re-using or integrating available well- developed open-source industry platforms, such as the Eclipse Arrowhead Framework[15], can be adapted to smart city needs based on requirements gathered in EU-funded projects. This is especially the case since industry sites are often integrated within city areas, and therefore naturally create synergies that can influence each other. These smart city applications create natural synergies with the System of Systems, Mobility and Digital Industry sections.

The impact of technology on environmental sustainability is likely to be highly significant. In retail, where shifting customer habits will be key (for example, for new products such as plant- or insect-based food), IoT sensors and devices will also yield a positive impact – for example, by reducing waste through improved food temperature or expiry date management. In the manufacturing sector, smart building applications related to energy and wastewater

[11] https://unhabitat.org/wcr/
[12] https://www.smartcitiesworld.net/news/ news/city-governments-fear-vendor-lock-in- from-iot-platforms-3776
[13] https://www.networkworld.com/article/967721/ibm-fuses-its-software-with-red-hats-to-launch-hybrid-cloud-juggernaut.html
[14] https://www.fiware.org
[15] https://www.arrowhead.eu

management, as well as applications such as carbon capture and biofuel generation on industrial sites, will have a significant impact.

Required R&D&I developments within ECS

Development of supportive infrastructure and a sustainable environment within EU needs the following specific R&D developments within ECS technology:

Specific R&D developments necessary	**ECS technologies**							
Major challenge 4: "Facilitate supportive infrastructure and a sustainable environment"	Process techn, equipm, materials & manufact.	Compoinents, miodules and system integration	Embedded SW & Beyond	System of Systems	Edge Comp. & emb. AI	Connectivity	Architecture & Design	QRSC
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4
Open systems and platforms for managing complex cross-connected physical infrastructure and associated processes		X	X	X			X	
Energy-efficiency oriented HW technologies and embedded SW	X		X		X	X	X	
Advanced cyber-security and privacy methods and tools						X	X	X
Intelligent connected IoT devices using new sensors for safety and resilience of EU societies	X	X	X	X	X	X	X	X
Ubiquitous, reliable, and energy-efficient connectivity and localization	X	X	X			X	X	X
Secure broadband low latency connectivity based on 5G systems and beyond	X	X	X		X	X		X
Distributed (production) systems		X		X	X	X	X	X

Figure 3.6.7 - Required R&D&I developments within ECS – Major Challenge 4

3.6.4. KEY ENABLING METHODOLOGIES

Key Enabling Methodologies[16] support in bridging the opportunities of the Key Enabling Technologies in ECS (electronic components and systems) with the four Major Challenges for the Digital Society. Key Enabling Methodologies (KEMs) are the 'instruments' that direct and structure the way of working in multi-collaborative settings, give direction and realise impact with useful applications and meaningful interventions.

KEMs contribute to the integration of the technological opportunities of ECS with the knowledge from design, social sciences, and the humanities about the Digital Society.

[16] https://kems-en.clicknl.nl

Several categories cover the main areas of the KEMs: Vision & Imagination, Participation & Co-creation, Behaviour & Empowerment, Value Creation & Upscaling, Institutional & System Change. KEMs can support in answering questions such as how technological tools, infrastructure and training can empower citizens towards digital inclusion. How to imagine and anticipate for setbacks and build collective resilience? How to include the relevant societal stakeholders into the R&D&I developments within ECS?

3.6.5. TIMELINE

The following table illustrates the roadmaps for Digital Society.

MAJOR CHALLENGE	TOPIC	SHORT TERM (2025–2029)	MEDIUM TERM (2030–2034)	LONG TERM (2035 and beyond)
Major Challenge 1: facilitate individual self-fulfilment	Topic 1.1: improved human– machine interaction solutions	Intensive research on human–machine interaction solutions	Improved human–machine interaction solutions in commercial phase	Ubiquitous human–machine interaction solutions
	Topic 1.2: online education and examination	Developments of methods and solutions for online education and examination	Online education and examination widely used across the EU	Online education and examination widely used world-wide
	Topic 1.3: VR/AR training and support	VR/AR pilots, including remote training, support, and work	VR/AR training, support, and remote work is mature	VR/AR training widely used across the EU
	Topic 1.4: support devices (wearables, robots, cobots, etc)	Smart watches and robots are commonly used devices	Support devices (wearables, robots, cobots, etc) gain more intelligence and interaction capabilities	Intelligent support devices (wearables, robots, cobots, etc) used in daily life
	Topic 1.5: nudging, gamification (for development or health reasons)	New nudging, gamification systems developed for education and health	Nudging, gamification pilots in education and health	Nudging, gamification (for development or health reasons) is widely used across the EU
Major Challenge 2: facilitate empowerment and resilience	Topic 2.1: access control/ intrusion detection/ surveillance	Developments of new sensors, devices, and algorithms for surveillance systems	Smart multimodal surveillance with AI-based intrusion detection	Smart multimodal surveillance with AI-based intrusion detection used world-wide

	Topic 2.2: reliable and ubiquitous digital infrastructures	Increased quality of service (QoS) and available bandwidth with 5G/6G, less time-critical functions moving to the cloud	Bandwidth and QoS increase especially for video-based applications Time-critical functions moved to cloud or edge-cloud systems	Bandwidth and QoS no longer an issue for video applications. AI algorithms support supervision. Edge-cloud systems are commonly used
	Topic 2.3: social media/serious gaming/AR/VR	AR on social media moves from photos to video >80% on social media in video by 2024; in-game systems that self-adapt to guide human learning. Use of cloud processing solutions.	Apart from, AR also VR for videos on social media Multimodal and multi-sensory interfaces in serious gaming Application beyond single game. Personal learning. Secured IP and cloud connected media content creation.	Real-time emotion state sensing Cognitive learning. Fully transparent , encrypted, and protected content creation with automation in the cloud.
Major Challenge 3: facilitate inclusion and collective safety	Topic 3.1: digital inclusion: tools, infrastructure, training, connectivity	Development of technologies (AR/VR, hearables, haptics, etc) for digital inclusion	Pilot deployments of hybrid systems for collective interactions	Technologies for immersive collective interactions
	Topic 3.2: resilient society against setbacks	Emergency/crisis response solutions and services with ubiquitous localisation	Trustable solutions for collective activity tracking, access control and intrusion detection	Trustable AI-supported hybrid solutions for resilient society
	Topic 3.3: societal acceptance of novel technologies	Technologies (serious gaming, nudging, etc) for societal acceptance and adaptation	Human-oriented trustable AI systems and technologies	Trustable AI for collective growth and well-being
Major Challenge 4: facilitate supportive infrastructure and environment	Topic 4.1: physical infrastructure management/ physical resilience	Development of IoT and dedicated robot-based inspection systems supported by AI algorithms	Pilot deployments of trustable AI-based systems relying on dependable edge/cloud IoT and unmanned solutions	Intelligent, affordable, and trustable IoT, robot-based systems, and unmanned solutions are available

	Topic 4.2: intelligent infrastructure management	Development of systems for intelligent management of infrastructure (water, street lighting, heat, etc)	Pilot deployments of trustable AI-based orchestration systems to create synergies in infrastructure management	Smart systems for multi-domain infrastructure orchestration and management available
	Topic 4.3: digital infrastructure management/digital resilience and cybersecurity	Acceleration of initiatives to create open, secure privacy- oriented systems; development of AI-based algorithms for increased cybersecurity	Adaptation and pilot deployments of available interoperable open and reliable systems supported by trustable AI algorithms for increased cybersecurity	Open, secure, interoperable, and reliable privacy-oriented systems empowered by trustable AI-based IoT solutions available
	Topic 4.4: surveillance, homeland security and emergency response systems	Edge/cloud solutions, IoT systems and robot-based inspection platforms, increased multimodal situational awareness, ubiquitous localisation	Deployment of trustable AI-based edge-cloud solutions, IoT systems and robot-based inspection platforms for surveillance and emergency response support	Trustable and dependable AI-based IoT systems and robot-based inspection platforms for increased situational awareness widely available